FEATURE EXTRACTION FROM ENGINEERING DRAWING FOR AXI-SYMMETRIC OBJECTS

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JANUARY 1990

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A Thesis Submitted
in Partial Fulfilment of the Requirements
for the Degree of

MASTER OF TECHNOLOGY

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to the

DEPARTMENT OF MECHANICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY KANPUR

JANUARY 1990

CERTIFICATE

This is to certify that the present work on "FEATURE EXTRACTION FROM ENGINEERING DRAWINGS FOR AXI-SYMMETRIC OBJECTS", by RAJESH KUMAR N. SINGI, has been carried out under my supervision and has not been submitted elsewhere for the award of a degree.

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ACKNOWLEDGEMENT

I praise God Almighty for his persistent grace.

I owe debts of gratitude and respect to my thesis supervisor Dr. J.L. Batra, for his expert guidance. I am thankful to him for his constant encouragement, plesant interaction and useful criticism.

I express my sincere thanks to my friend Sanjeev Khadilkar for the fruitful discussions I had with him regarding the present work, and for rendering paternal support during my stay at IIT Kanpur.

I would like to thank all my friends Manohar, V.S. Rao, Venu, Avadhesh, Anil, Pankhawala, Joshi, S.N. Murthy and all those who made my stay at IIT Kanpur A memorable one.

RAJESHKUMAR N. SINGI

ABSTRACT

Computers are used both in design and manufacture. In design, they are used primarily for the purpose of modeling, analysis and drafting while in manufacturing they are used to control the tool motion in cutting processes. A survey of the literature suggests that in reality fully computerized integration of both design and manufacturing functions has not been realized. This realization forms the corner stone for the unmanned factory of the future. The present thesis is an attempt towards interfacing of CAD/CAM over the limited domain of axi-symmetric parts.

The growing exchange format output of the drawing drawn in drafting software viz., AutoCAD is used as as input for the rule based feature extraction methodology. Information about the superfluous lines and arcs is removed through data merge operation. The feature extraction software identifies in detail the various internal, external and auxiliary profiles for both the blank and finished objects. An intelligent concatenation of these profiles gives a profile which when rotated about an axis of symmetry generates the required part and blank configuration. The output of the feature extraction software becomes available in two formats viz., CIMS/DEC and Profile Segment Description. The proposed feature extraction software has been developed for the UNIX environment using 'C' programming language. An illustrative example is given to demonstrate the capability of the software.

The proposed software has been integrated with an existing CAPP software. The integration is accomplished through the CIMS/DEC format. Two illustrative examples are considered to demonstrate the integration of the feature extraction and the CAPP softwares.

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CHAPTER I

INTRODUCTION

Since last two decades, the competition in consumer market as well as capital market has increased rapidly. To stand in such a highly competitive market the industries have been improving their products constantly and are trying to reduce the various costs of their products. Therefore, design and production are getting more and more attention along with other activities like marketing, sales etc. as trends have been changed from producer's market to buyer's market.

Changes in the market trends have also resulted in the development of newer manufacturing philosophies. Traditional high volume production has now become batch production. This has changed old workshops into a flexible manufacturing systems. To cope up with this new challenge it has become necessary for the industries to speed up various functions such as design, planning, manufacturing, scheduling, and assembly etc. Computers have played a very significant role in the changed manufacturing environment.

Computers are used both in design and manufacture. In design, the computers are used for the purpose of modeling, analysis and drafting while in manufacturing they are used to control the motion of the tool in the cutting process. This has improved the productivity and overall efficiency considerably. But, still, there is scope for improvement as the integration of design and manufacturing has not been fully realized in reality.

For example, translation of design data into manufacturing information is done either manually or with the use of computers in the interactive mode. This is a time consuming and laborious process and needs a lot of experience and expertise. This process of translation of design data into manufacturing instructions is called process planning.

Since the beginning of the last decade it has been recognized by both academic and industrial communities that planning in manufacturing environment is vital in achieving the ultimate goal of unmanned and integrated factories in the future. Planning is not only a key link between design and manufacturing within a production environment but is also a decisive activity which distinguishes a smooth running factory from a chaotic one. To date many research and development efforts have been devoted to analyzing, modeling and automating such planning activities. Many Computer based systems like CAM-I CAPP, GENPLAN, CORE-CAPP, DCLASS, APPS, CPPP and TIPPS [2] have been developed which successfully demonstrates the great potential of these efforts. As the need to integrate design and manufacturing increases the needed for more robust and automated planning system will also increase accordingly.

1.1 WHAT IS A PROCESS PLANNING ?

Planning is an intrinsic part of intelligent behavior. In generic view, planning can be viewed as the activity of devising means to achieve desired goals under given constraints

and with limited resources. Thus, three basic components of any planning activity are goals, constraints, and resources. An intelligent planner whether a human being or computer should have ability to understand, represent and manage these three components.

The purpose of process planning is to select and define in detail the processes that have to be performed in order to transform raw material into a given shape. The primary objective is to define feasible processes. Cost and throughput are secondary objectives and available resources (machine tools, cutting tools, and labour) act as constraints. Process planning includes :

- selection of machine tools,
- selection of tool sets,
- selection of set ups,
- selection of machining operation and their sequence,
- selection of cutting tools,
- design of jigs and fixtures,
- calculation of cutting condition,
- determination of tool path, and
- NC part program generation.

All of the above functions can not be performed unless the important features of the part are understood fully. Thus feature extraction of the object to be planned is a key factor in

the total automation of process planning and CAD/CAM integration.

1.2 COMPUTER AIDED PROCESS PLANNING

Three major approaches were tried in computerization of process planning. These are detailed below:

1.2.1 VARIANT APPROACH :

Some of the earliest work in applying computers to aid the process planning task has been in the area of variant process planning systems. In this type of CAPP systems, parts are grouped into part families, a unique code is generated for each family, and standard process plan is developed beforehand for each family. Most systems use a well-defined Group Technology (GT) based coding system to develop the unique code for the various part families. The standard plans are stored in the computer, conveniently keyed under the unique code generated for each family. This type of process planning is used by first developing the code for a new part to show which part family it belong to, and then retrieving and filling in the standard process plan to reflect the characteristics of the new part. COMCAPP V (developed by MDSI) is one of the well known examples of such computer aided process planning systems.

1.2.2 SEMI-GENERATIVE APPROACH :

Semi-generative systems were the next generation of process planning systems. These systems are advanced variant systems, incorporating quasi-generative features. After part

family has been identified, as in basic variant system, these systems offer the user several options. One option is to make suitable changes to the standard process plan for each part family. The second option is to begin with an incomplete process plan and complete for a specific part. A third option is to start from the beginning and completely create a new plan by using various standard process descriptions stored in the computer. Preliminary version of GENPLAN (developed by Lockheed-Georia Co.) and CORE-CAPP [12] are some examples of such systems.

1.2.3 GENERATIVE APPROACH :

The generative approach marks a notable change in the evolution of computer aided process planning systems. These systems are designed to automatically synthesize process information to develop the process plan for a part. These systems contain the logic to use manufacturing data bases and a suitable part description systems to generate a particular part. Early version of the generative process planning systems used decision tables and decision trees to capture manufacturing logic, and GT code or specially developed language to provide a precise description of the part.

These systems, being more complex than their variant counterpart, were also restrictive in the breadth of their application. XPLANE [11], APPAS (developed at Purdue University) and CPPP are some of the systems of this kind. With the advent of CAD data bases and wire frame modeling generative process planning systems are being developed using this type of part

description scheme. TIPPS and RPO are some of early systems to explore the link between CAD data bases and generative approach for process planning.

Currently, the research in the area of CAPP is more focused on the issue of integration of design, planning, and manufacturing tasks. But as mentioned earlier, CAD and CAM progressed separately creating a gap between designer and manufacturing engineer. Though information is conveyed through part drawings a lot of information remain hidden or superfluous. This is a major hurdle in the integration of CAD and CAM. Thus, the description of geometrical and topological features of a part has been realized to be a central link between the tasks at all these levels.

1.3 NEED OF FEATURE RECOGNITION

As mentioned earlier, the designer's intention may not always be clear to manufacturing engineer who will act on that intention. The respective languages used in their profession, the ways in which they express their intentions, their critical concerns, and their perspective may all differ. Designer generating the drawings is often not aware of constraints and limited resources that the manufacturing engineer has to deal with while carrying out these intentions. This results in chaotic execution of plan or greater cost.

In order to circumvent these problems, it is required that the automated process planning system provides for an

automatic part feature extraction from product model without human interaction. However, existing interfaces of CAD systems do not sufficiently consider this requirement of process planning. Needed information may be inaccessible or in inappropriate form. Engineering drawing are the medium currently used by designers to communicate with manufacturing engineers, but these drawings may sometimes contain insufficient data or the data may be in hidden form which can not be directly used, or extraneous data may be included which obscures the relevant information.

1.4 LITERATURE SURVEY

Researchers have attempted different approaches to develop a generalized feature recognition system for CAD/CAM integration. However, most of the efforts are limited to non-rotational parts only and are based on syntactic pattern recognition technique. Further, from the available literature, it is observed that most of the researchers make use of solid modeler for an object representation as well as for feature extraction. The feature extraction module makes use of internal representation of the solid modeler. The survey of the research efforts shows that most of the efforts have been made for prismatic parts. The internal representation of the solid modeler is used for this purpose and syntactic pattern recognition technique is adopted. Therefore, it can be deduced that this field is wide open for research.

Kakino's paper [6] was the first step in the direction

of developing generalized feature recognition system. He developed a part description method on the basis of the fundamental concept of converting the part drawing information into computer oriented information for the data structure. This method is applicable to all objects generated by sweep (either translational or rotational). He considered a reference surface to be a set of concatenated profile elements, both technological (e.g. surface roughness, tolerances, etc.) and topological (e.g. dimension, etc.) associated with it. This reference surface when revolved around an axis of symmetry generates an axi-symmetric object. The same surface when translated generates a prismatic object.

The proposed part description method CIMS/DEC (Computer Integrated Manufacturing System/ Description Method) stores both technological and geometrical information of the reference profile in a compact and easy to process format. The present work extracts information from engineering drawing and converts it into CIMS/DEC format. The details of this format are presented in Chapter 3.

Woo [7] proposed a method for extracting features from an object's CSG (Constructive Solid Geometry) representation. In this method objects are defined by a restrictive form of CSG and the volumetric features of the objects are considered. The CSG representation of the object is searched by use of an AI technique to extract patterns that match the feature definition. His implementation extracted some very simple

features from objects in a narrow domain.

In 1982 Woo [9] proposed a volume decomposition method. He suggested a decreasing convex hull algorithm for volume decomposition. In this method, the difference between the convex hull and the object is computed recursively until the null set is obtained.

Kakazu [8] proposed an approach to generate GT codes for axi-symmetric parts from a solid modeler using CSG representation. The generated code refers to geometry code, macro geometry code and semantic codes.

UMIST has developed expert system called EXCAP [10] for automatic feature recognition of axi-symmetric features and automatic selection of cutting tools and cutting sequences. EXCAP seeks to recognize features automatically which can be machined in one operation, e.g., right hand shoulder, undercut, drilling hole etc. It is implemented in PROLOG and is interactive with the user. Prolog allows multiple solutions to problems so that only a relatively small number of fuzzy patterns are required to identify all the patterns in a very complicated component. A fuzzy pattern in this context could be a groove with loosely defined top and bottom corners, i.e., chamfered or rounded or none of these. The patterns represent the metal to be removed next instead of the work piece, thus allowing no realistic limits to the complexity of the component to be planned. Once patterns are recognized, they are examined

by the system to select the preferred filling in operation as a step towards blank. In 2D, the geometry is matched by the feature recognition templates which consist of sequence of surface elements.

Li [5] has developed a part feature recognition system for rotational parts without deviation, i.e., axi-symmetric objects. In the system, the 3D-profile is represented as a simple connected, directed graph. The concept of graph theory and syntactic pattern recognition techniques have been used to identify profile information extracted from CAD data base. The recognized information is stored in a part feature definition data structure, which is accessible to manufacturing functions such as computer aided process planning, group technology coding, NC part program generation and inspection. Part definition data from CAD systems is extracted via IGES standard data format.

Requicha [9] has made a survey of research efforts in the area of pattern recognition. This paper presents various approaches used in the feature recognition.

1.5 SCOPE AND ORGANIZATION OF THE WORK

Present work is an attempt on feature extraction from drawings. As computers are used widely in drafting, this work takes input drawing drawn in the drafting software viz., AutoCAD. Moreover, the present work has been confined to simplest family of the object, i.e., axi-symmetric components. The approach is

primarily rule based and has been implemented in C on Apollo Workstations.

The present software generates output in two different formats, viz., CIMS/DEC format and the profile segment description format. The output in CIMS/DEC format can be used for interfacing with other process planning softwares. The profile segment description format can be used for the generation of manufacturing database which can provide information group code generation and process planning, etc. However, in the present work, the CIMS/DEC format output has been interfaced on the upstream side of the CAPP software developed by Narayana [13]. The CAPP software has been suitably modified to achieve smooth interfacing.

Input to the software is a DXF output of drawing drawn in Autocad. Drawing should satisfy certain constraints. These constraints and DXF format are explained in chapter 2. This chapter also explains need of data files/structures used in the implementation.

Chapter 3 outlines the approach used in feature extraction and use of drawing conventions in the approach. It also discusses output format and use of output data structure in feature recognition.

Chapter 4 explains test runs and the results obtained are displayed. It gives, in brief, information about the software and also explains significance of the error massages

displayed.

Chapter 5 is concluding chapter in which suggestions for future work are mentioned. A User's Manual is appended at the end.

CHAPTER II

INPUT FORMAT AND DATA STRUCTURE

In this chapter input format for the software is discussed along with the data structure needed for the storage of the same. The translation of drawing data into manufacturing information is carried out in stages. In fig 2.1 an overview of the proposed system is depicted in the form of a flow diagram.

In computerized drafting, drawing data base is stored in a very compact format as size of database is very large. The data storage formats, which are very compact, vary from machine to machine in order to get the best performance on the particular computer. These compact formats are very hard to read using user's programs. In order to facilitate the exchange of information from the drafting softwares as well as drawings , it is necessary to have a standard format. This format should cover all the information about the drawing and at the same it should be easy for processing by the user programs. IGES(Initial Graphics Exchange Standard) format and DXF (Data Exchange File) formats are two such formats. In the present work DXF format is used for exchanging drawing information. Further, AutoCAD is used to provide DXF input of the drawing.

2.1 STRUCTURE OF DXF FILE

DXF (Drawing Exchange File) is a simply an ASCII file with specially formatted text. The format is

constructed such that it should be easy to read necessary information and ignore the superfluous one. For example, by virtue of specially formatted text, Autocad setting variables in the DXF file can be ignored.

In DXF files, the drawing information is organized in four parts which are briefly described below :

1. **HEADER Section** : General information about the drawing (e.g., limits of drawing, units, scale, etc.) is found in this section of the DXF file. Each parameter has a variable name and an associated value.

2. **TABLES Section** : This section contains definitions of named items like linetype, layers etc. There is an entry for each of defined /used linetype and layer.

3. **BLOCK Section** : This section contains block definition entities. The entities comprising each block in the drawing are described. Block in Autocad drawing is a set of user defined entities with the name tag attached to it. User can call this block by the name to draw entities defined in the block.

4. **ENTITIES Section** : This section contains the drawing entities, including any block references.

A DXF file is composed of multiplicity of groups, each of which occupies two lines in the DXF file. The first

line of a group is the group code, which is a positive non-zero output in the FORTRAN "I3" format. The second line of the group is the group value. This is in a format which depends on the type of group as specified by the group code. Fig 2.2 shows the structure of the DXF file. More information on DXF files can be found in Autocad manual [4] at Page 370.

Autocad drafting software provides various facilities of defining user's own linetype styles as well as curves like B-spline, spline etc. However, the present work does not consider these curves and user defined linetypes. The drawings are drawn keeping the following constraints in view :

1. Drawing should be drawn using Autocad defined CONTINUOUS, DASHED and CENTER linetypes are used.

2. As for as possible lines of different line type should be drawn in different layers.

3. Drawing should contains only lines and arcs/circles, which may be drawn using line, Pline, arc or circle commands of AutoCAD software.

4. All drawing dimensions should be in mm only.

5. Drawings drawn using AutoCAD should be true to scale.

6. AutoCAD drawing should not contain any dimension lines.

7. Drawing should contain only one view of the object

```
   0      <---  Group  Code  for   --->      0          SECTION
               file partioning          SECTION  --\
   2                                      2         |
 HEADER    --\                           BLOCKS     |
   9         |                            0         |--> BLOCKS
 $ACADVER    |                           -- --      |    Section
   1         |---> HEADER Section        -- --      |
$ACADV       |                           ENDSEC  --/
 -- --       |                             0
 -- --       |                           SECTION
 $WORLDVIEW  |                             2
  70         |     Section Name --->    ENTITIES  --\
      1      |                             0        |
   0         |                           POLYLINE   |
 ENDSEC   ---/                             8        |
   0                                    0           |
 SECTION             Group Code --->     66         |
   2      --\        Group Value ->        1        |
 TABLES     |                             10        |
   0        |                            0.0        |-> ENTITIES
 TABLE      |                              0        |   Section
   2        |                            VERTEX     |
 LTYPE      |--> TABLES Section            8        |
  70        |                               0       |
 -- --      |                              10       |
 -- --      |                            -- --      |
   0        |                            -- --      |
 ENDTAB     |                             2.0       |
   0        |                            0          |
ENDSEC      |                           ENDSEC  ----/
          --/                               0
                                        EOF  -> End of File Flag
```

Fig 2.2 Structure of DXF file.

and that must be a view on a plane parallel to axis of symmetry. However, orientation of figure does not impose any constraint.

8. Drawing conventions should be followed strictly.

Present work takes care of drawing errors like discontinuity of lines (up to .05 mm), deviation of slope of line from the actual (up to .05 degrees), etc.. Further, it removes overwritten lines and arcs. Details regarding creation of input file can be found in the users manual given in the Appendix.

A DXF input file provides input to the decrypting module of the proposed feature extraction software. In the decrypting module, firstly, header variables of the drawing viz., limits, unit specifications, etc., are read. This is followed by reading the tables for various attributes like linetype and layers. Next, the blocks and entities section containing information about lines and arcs is read.

For constructing a line, we need to have two points (X1,Y1) and (X2,Y2). Other attributes of the line like slope and X or Y intercept are also stored. For defining an arc, the radius of the arc, co-ordinates of the center, start and end angle of the arc are required. Other attributes like start point and end point are also stored. Initially, the information about arcs and lines is stored separately in

linked lists for lines and arcs. However, after correction /removal of superfluous entities, they are stored together in one linked list.

2.2 DATA STRUCTURE FOR LINES

Each node of the linked list for lines contains following fields.

1. X1 co-ordinate.
2. Y1 co-ordinate.
3. X2 co-ordinate.
4. Y2 co-ordinate.
5. Slope of the line (inclination with positive X-axis).
6. X intercept if line is parallel to Y-axis, else, Y-intercept.
7. Pointer to next node of higher X1 or Y1 value.
8. Pointer to next node of higher slope value.
9. Pointer to next node of higher intercept value.

First six fields are stored as an arrary. Last three fields in the above list are for the purpose of indexing linked list on the following fields.

1. X1 value of line if line is not parallel to Y-axis, else, Y1 value,
2. slope of the line, and
3. line intercept.

Once the co-ordinates of the lines are known, their slopes in radians is calculated. If the line is parallel to Y-axis (i.e. for slope with value $\pi/2$ radians) then Y intercept is calculated, else, X intercept is calculated. Next, the lines are checked for the following conditions.

1. For lines parallel to Y-axis; $X1 < X2$ and
2. For lines parallel to X-axis; $Y1 < Y2$.

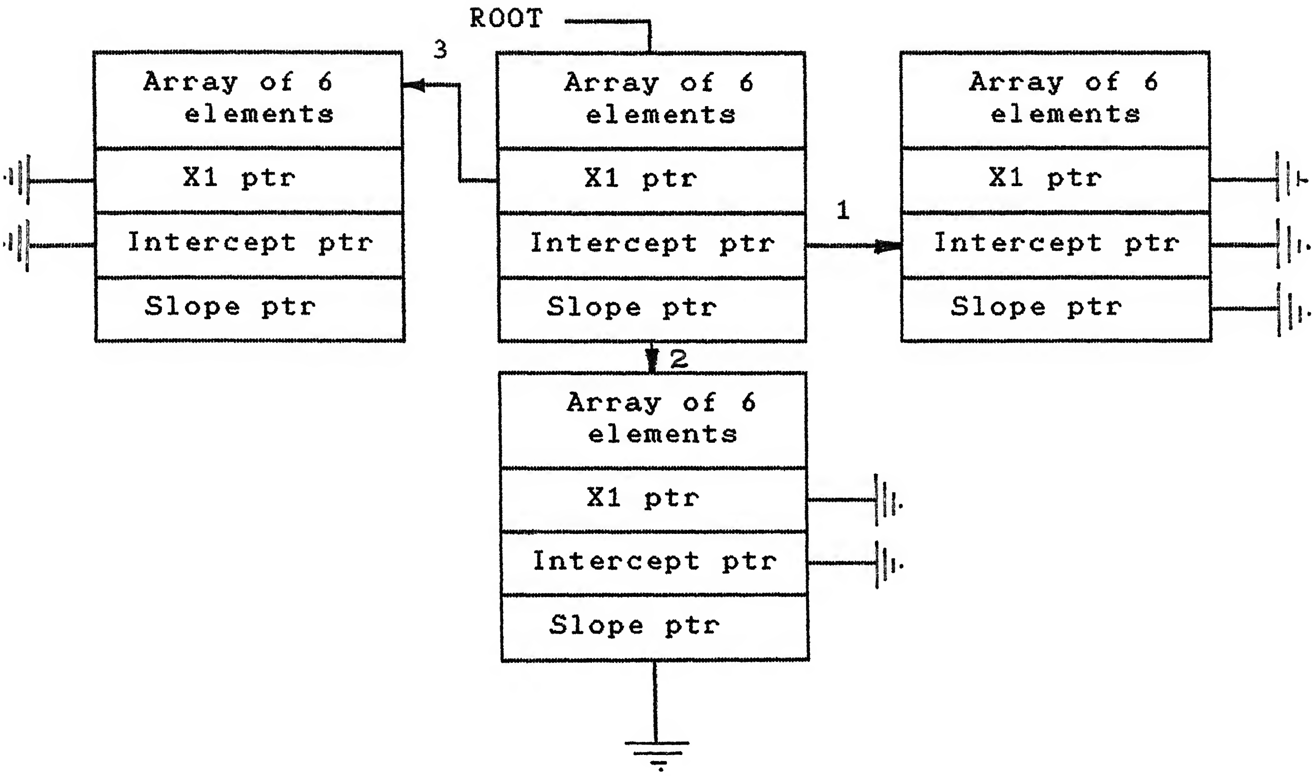
If the above conditions are violated, end points are swapped to satisfy these conditions. Next, the node data is appended to the linked list in a manner such that the following conditions are satisfied.

1. Nodes with same value of slope and intercept are arranged in ascending orders of X1 values for lines not parallel to Y-axis, else, they are arranged in ascending order of Y1.

2. Nodes with same slope are arranged in ascending order of the intercept values.

3. Nodes with different slopes are arranged in ascending order of the slope.

This links all the nodes with same slope and intercept (i.e. collinear lines) along X1 pointer in ascending order of values of X1. This helps in the removal of superfluous data. Fig 2.3 shows the structure for the linked list of lines.



1 : Intercept link connects nodes of the lines, with same slope but different intercept values, in the ascending order.

2 : Slope link connects the nodes of the lines, with different slopes, in the ascending order.

3 : X1 link connects nodes of the lines, with same slopes and same intercept but different start points, in an ascending order.

Fig 2.3 DATA STRUCTURE FOR LINE

2.3 : DATA STRUCTURE FOR ARCS

Each node of the linked list for arcs contains following fields.

1. Xc : X co-ordinate of center.
2. Yc : Y co-ordinate of center.
3. X1 : X co-ordinate of start/end point of an arc.
4. Y1 : Y co-ordinate of start/end point of an arc.
5. X2 : X co-ordinate of start/end point of an arc.
6. Y2 : Y co-ordinate of start/end point of an arc.
7. S_angle : start angle of an arc.
8. E_angle : end angle of an arc.
9. Rad : radius of an arc.
10. Flag to indicate whether (X1,Y1) pair corresponds to start point or end point.
11. Pointer to next node with higher value of Xc.
12. Pointer to next node with higher value of Yc.
13. Pointer to next node with higher value of radius.
14. Pointer to next node with higher value of start angle.

First ten fields are stored as an array. Once the information about an arc is read, all required parameters are calculated. Initially, points (X1,Y1) and (X2,Y2) which correspond to the start and end points of the arc, respectively, are determined. However, they are checked for the condition X1 < X2. Else, these points are swapped and the flag is made true. Next, arc data is arranged in the linked list in such a manner so as to satisfy the following conditions:

1. Nodes with same value of Xc, Yc and radius are arranged in ascending order of S_angle.

2. Nodes with same values of Xc and Yc are arranged in ascending order of radius value.

3. Nodes with same values of Xc and Yc are arranged in ascending order of Yc value.

4. Nodes with different values of Xc are arranged in ascending order of Xc value.

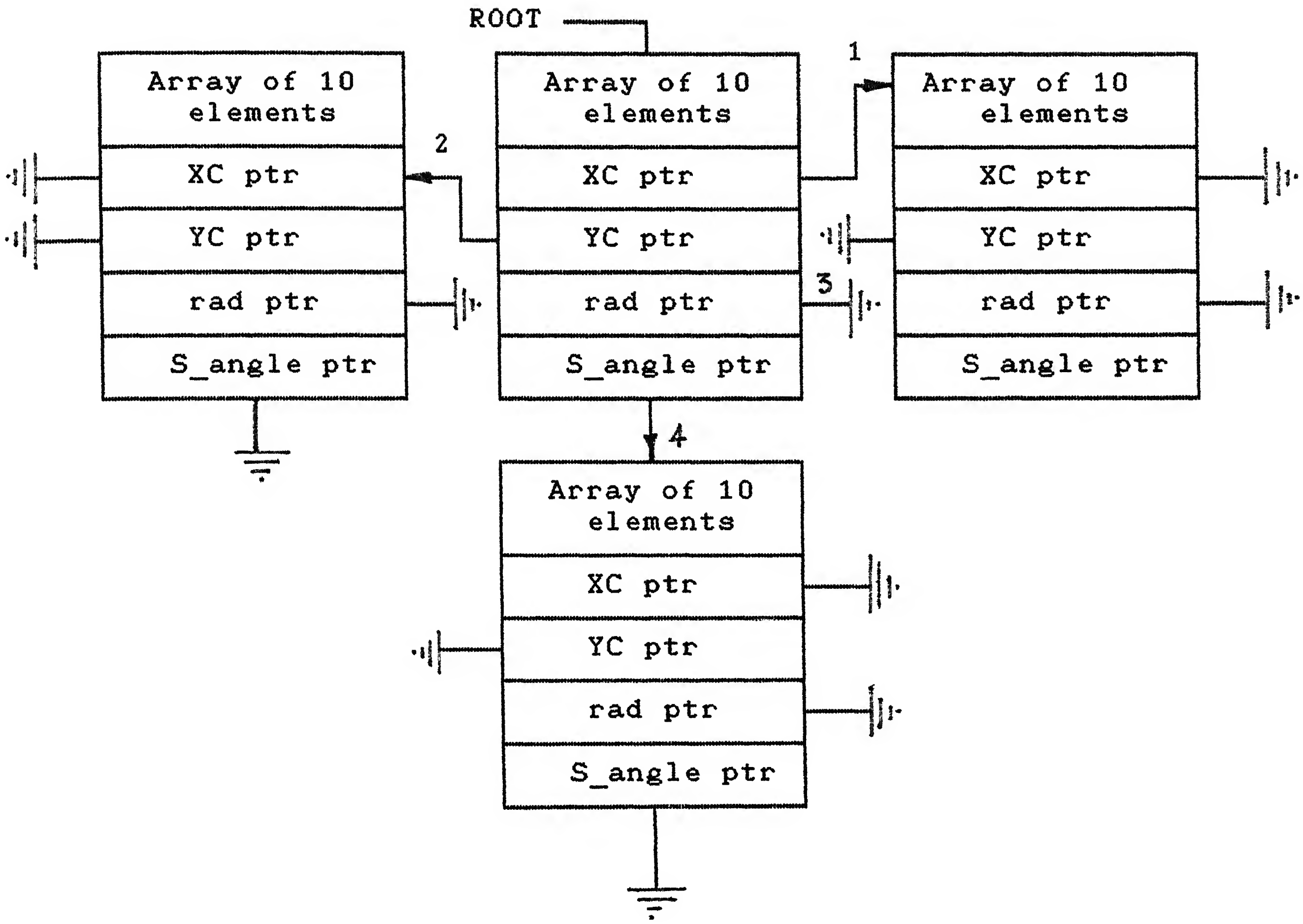
This arranges all arcs having same center and same radius in the ascending order of the start angle. This also helps in the merging of overwritten arcs. Fig 2.4 shows the structure for linked list for of arcs.

2.4 REMOVAL OF SUPERFLUOUS DATA AND MERGING

Operation merge-line and merge-arc are performed on linked list for lines and arcs, respectively, to remove redundant lines and arcs in the drawing. The MERGE-LINE and MERGE-ARC procedures are outlined below.

2.4.1 MERGE-LINE :

In this operation, linked list for the lines is traversed along X1 pointer till it becomes NULL. This is repeated for each node on intercept and slope links. In case of lines which are not parallel to the Y-axis, a node is deleted if it satisfies the condition that X1 of node is less than X2 of the previous node. For lines parallel to Y-axis, instead of X1, Y1 value is compared with Y2 value of the



1: Xc-Link connects nodes of arc with different values of x-coordinate of center (in an ascending order).

2: Yc-Link connects nodes of arc with same values of xc but different values of yc (in an ascending order).

3: Rad-Link connects nodes of arc with same values of xc and yc but different values of radius (in an ascending order).

4: S_angle link connects nodes of arc with same values of xc, yc and radius but different values of s_angle (in an ascending order).

Fig 2.4 DATA STRUCTURE FOR AN ARC

previous node. The node co-ordinates of previous node are modified in the following way and current node is deleted.

1. In case, lines which are not parallel to the Y-axis, if X2 value of the current node is greater than X2 of the previous node, (X2,Y2) value of the current node is assigned to the previous node, else, values of the previous node remain unchanged.

2. For lines which are parallel to Y-axis, if Y2 value of the current node is greater than that of the previous node, (X2,Y2) of the current node are assigned to the previous node. Else, the values of the previous node remain unchanged.

This merge line operation merges all collinear intersecting or overlapping lines into one line. This avoids error in the search operations which are performed in the succeeding modules.

2.4.2 MERGE-ARC

Linked list for arc data is traversed along S_angle pointer, till it becomes NULL. This is repeated for each node on Xc, Yc and radius links. A node is deleted if the start angle value of node is less than end angle value of the previous node. If end angle value of the current node is greater than that of the previous node, it is assigned to the previous

node. Else, end angle value of the previous node remains unchanged.

Merge arc operation merges all intersecting and overlapping arcs with common center and same radius. This avoids error in the search operations performed in the succeeding modules.

2.5 DATA STRUCTURE FOR FEATURE EXTRACTION

After reading HEADER and TABLES sections, all lines with linetype 'CENTER' are read and stored in linked list. These are merged to give non-redundant set of center lines of the drawing. In such a set, line with greatest length corresponds to the axis of symmetry of the object. If the axis of symmetry is inclined, the figure is rotated so as to make the axis of symmetry parallel to X-axis.

Next, all entities including linetype 'CENTER' are read and multiplied by rotation matrix. The lines with different linetypes are stored in different linked lists. Similarly, the arcs with different linetypes are stored in different linked lists. Merging operation is performed on these lists. Lists of lines and arcs of same linetype are now stored in a structure which accommodates data for both the entities. This data structure has the following fields.

1. Curve type - Line/Arc.
2. Array of 10 elements. If curve type is

line then, the first six elements of these arrays stand for first six fields of the line data structure. Else they correspond to the first ten fields of an arc data structure.

3. Pointer to next node with same value of X1.

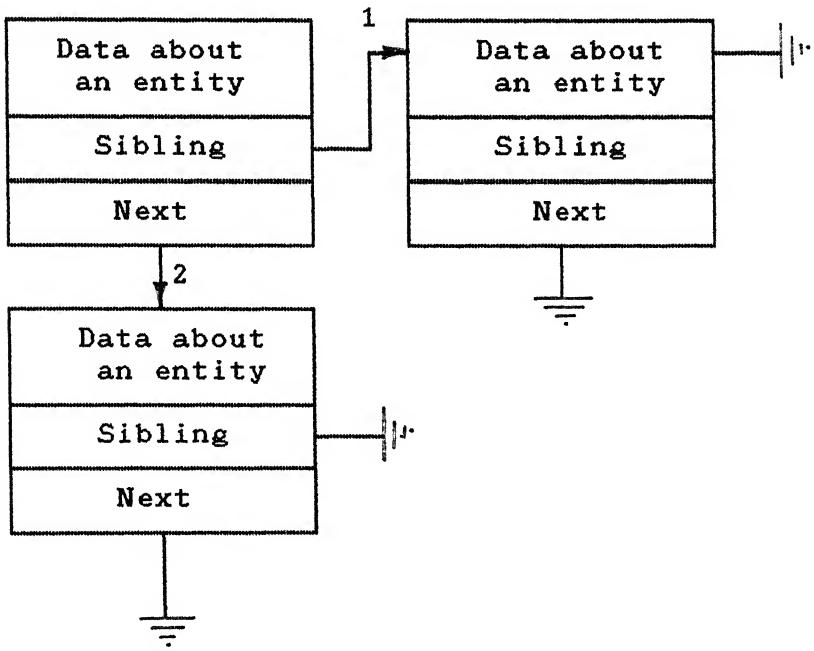
4. Pointer to the node with higher value of X1.

The foregoing common data structure also stores data in the form of linked list and satisfies the following conditions.

1. Nodes with same value of X1 are arranged along pointer "sibling".

2. Nodes with different value of X1 are arranged in ascending order along pointer "next".

The common data structure obtained for lines and arcs serves as data file for the succeeding modules. There are three different files for three linetypes CONTINUOUS, DASHED and CENTER. Fig 2.5 depicts the procedure used for obtaining the common data structure.



1: Sibling link connects entities with the same values of x1.

2: Next link connects the entities with different values of x1 in an ascending order.

Fig 2.5 : DATA STRUCTURE FOR DATA FOR SEARCH OPERATION

CHAPTER III

METHODOLOGY AND OUTPUT

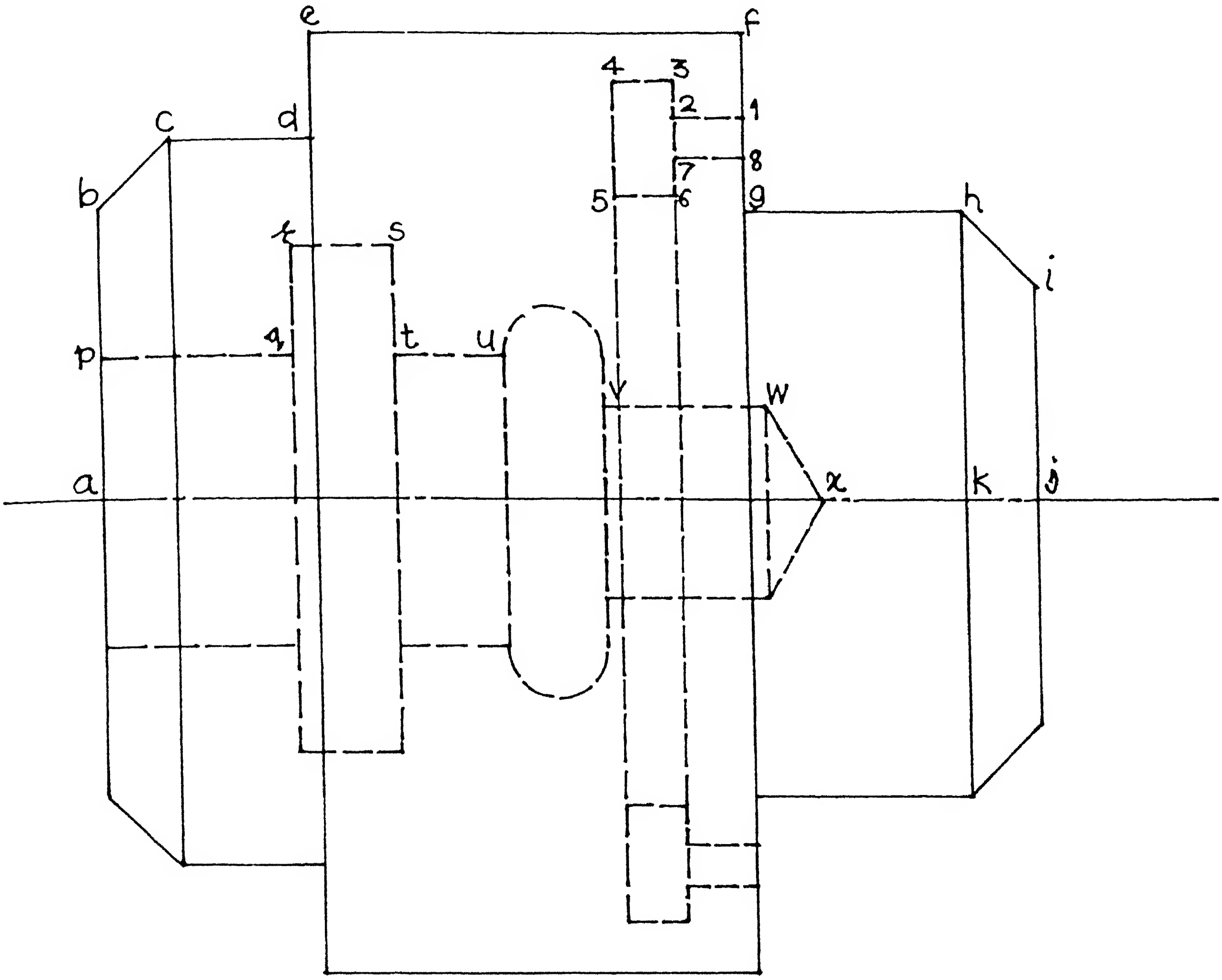
3.1 DOMAIN OF THE PRESENT WORK

With the approach followed inthe present work, the features like knurling, internal threading, etc. are difficult to recognize. Therefore, the domain of the present work can be defined as axi-symmetric objects without threads, taps ,knurls, etc.

In the present work, the terms "external features", "internal features" and "auxiliary features" are used and are explained pictorially in fig 3.1 . The features that lie along continuous lines are defined as external features while the features that lie along the axis of symmetry and are enclosed by at least one dotted line are called internal features. Auxiliary features are those which are neither external nor internal. These features are enclosed by combination of dotted line (s) and a continuous line and do not lie along axis of symmetry. In fig 3.1, features along a-b-c-d-e-f-g-h are external features, while those along p-q-r-s-t-u-v-w-x are internal features. An auxiliary feature is depicted by 1-2-3-4-5-6-7.

3.2 METHODOLOGY FOR EXTERNAL FEATURE RECOGNITION

The output of the preceding module gives linked list for drawing data of an axi-symmetric object without redundant (overlapping) entities and with axis of symmetry parallel to the X- axis. The search is made, in the



External Feature Profile : a-b-c-e-f-g-h-i-j

Internal Feature Profile : p-q-r-s-t-u-v-w-x

Auxiliary Feature Profile : 1-2-3-4-5-6-7

Fig 3.1 FEATURESOF AN AXI-SYMMETRIC PART$

linked list for entities with linetype CONTINUOUS, for an entity which satisfies the condition that at least one of its endpoints lies on the axis of symmetry. This search is made if there is no arc which crosses the axis of symmetry and is having its start angle less than 180 degrees. This is verified while copying arc data from data structure for the arcs to common data structure. The first entity thus found is called the left boundary of the external feature. The node corresponding to the left boundary is deleted from the linked list and forms the root of the linked list for the external features.

Now the search is made for the entities having start point (X1,Y1) equal to the endpoint of the left boundary (X2,Y2). If arc is encountered with such a start point (X1,Y1) (not to be confused with the start point of the arc) ,the search is terminated and the node, thus, found is deleted from the linked list and appended to the "next" pointer of the root. Otherwise, the search is continued. At the most two entities can be found in the linked list satisfying this constraint (This can be followed easily from the study of drawing conventions.). In such cases, entity having Y2 greater than Y2 of the left node is selected. In case, both the entities have Y2 less than Y2 of the last node in the external feature list (i.e. the left boundary in the present case), then cosine of included angle between left node and each entity is calculated and the one having lower value is selected.

The selected node is deleted from the linked list and appended to the next pointer of the root of the external feature. Fig 3.2 shows the linked list for features. If no entity is not found in the above search ,then the search is performed for an entity satisfying the following conditions.

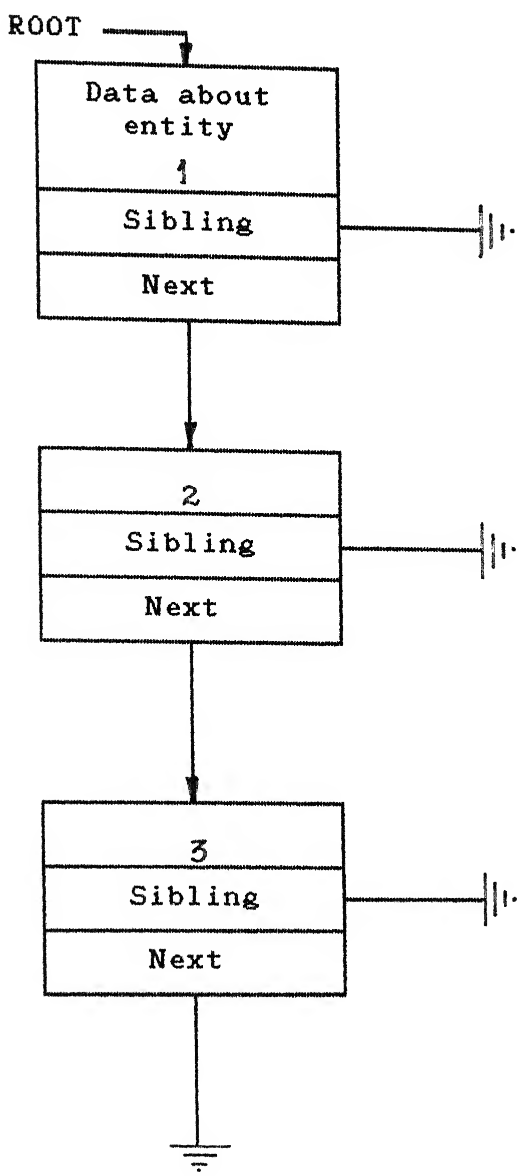
1. It is parallel to the Y-axis.

2. Its X-intercept is equal to X2 of the left boundary.

3. Its Y1 value is less than Y2 of the left boundary and Y2 is greater than that of the left boundary.

The entity, thus found, is deleted from the linked list and (X2,Y2) of the left boundary is assigned to (X1,Y1) of the current node.

If the above search does not identify any entity, then "drawing incomplete" error is indicated. Next, the search is made for next entity in the external feature list with the newly found entity's endpoint as the basis of the search instead of the left boundary's end point. The entity thus found is appended at the end of the linked list for the external feature. If the entity, thus, found is parallel to the Y-axis then a check is performed to see whether Y1 is equal to Y2 of the last node in the external feature linked list. If this condition is not satisfied (i.e. Y2 is equal to Y1 of last node in the external feature linked list) the point is swapped before appending this node to the external feature list.



1. For all nodes "Sibling" link is NULL.
2. Selected entity is appended at the end of the list.
3. First node is called left boundary and the last one is called as right boundary.

Fig 3.2 DATA STRUCTURE FOR STORING PROFILE DATA

If the last node in the external feature list is a line parallel to the Y-axis and has Y1>Y2, and Y2 is less than Y-intercept of the axis of symmetry, then the value of Y2 of the last node in the external feature list is made equal to the value of Y-intercept of the axis of symmetry. Next, the search is performed for a line/arc having X1 value equal to X1 value of the previous node and Y1 value greater than Y2 of the previous node. If a node which meets such a description is found, Y2 of the last node in the external feature list is made equal to Y1 of the newly found node and the newly found node is appended to the external feature list. The search operation is terminated if the following conditions are satisfied.

1. The last node of the external feature list is a line which is not parallel to the Y-axis and has Y2 equal to Y-intercept of the axis of symmetry or it is an arc with Y2 value less than or, equal to Y-intercept of the axis of symmetry. If Y2 of an arc is less than Y-intercept of the axis of symmetry; Y2 value of this arc is made equal to that of the Y-intercept of the axis of symmetry and the start angle is set as zero.

2. The last node is a line parallel to the Y-axis and has Y2 equal to the Y-intercept of the axis of symmetry and the search operation for an entity meeting the following condition fails: X1 value of an entity is equal to the X1 value of the last node in the external list and Y1 value is greater than Y2 of the last node of the external list.

The tail of the external feature list thus obtained is called the right boundary.

3.3 RECOGNITION OF BLANK BOUNDARY

For recognition of the blank boundary, a procedure similar to the one used for recognition of the external feature is followed and the search is performed on the linked list containing data of linetype "DASHED". However, the first element, i.e., left boundary should have X1 less than that of the left boundary of the external feature. If the search operation fails ,it is assumed that the blank is not defined. In such a situation, the blank dimensions are calculated by considering the left boundary, right boundary and the fartherest Y point in the external feature list.

The foregoing discussion implies that the present work fails to recognize blank boundary if it coincides with any of the finished part boundary. However, this problem can be circumvented by drawing both the dashed and continuous lines even if they overlap.

3.4 RECOGNITION OF INTERNAL FEATURES

Basic knowledge of engineering drawing suggests that if the left boundary is not a line parallel to the Y-axis, there will not be any internal feature on the left hand side of the object. Similarly, if the right hand side does no satisfy same constraint, there will not be any internal feature too.

We know that an internal feature can be a through hole. For a through hole, X2 of the last node in the internal feature list would be equal to X2 of the right boundary of the external feature and Y2 of the last node would be greater than or equal to Y2 of the right boundary of the external feature. Further, Y2 of the last node would be less than Y1 of the right boundary of the external feature. In case of a through hole, there is no need of any search for the right internal features.

3.5 AUXILIARY FEATURE RECOGNITION

The search for auxiliary features is performed on "DASHED" linetype list. The search is made only when a node in the external feature list indicates a line parallel to the Y-axis. The search is made for an entity having (X1,Y1) or (X2,Y2) lying on this particular node. The list of auxiliary features is appended till an entity ending on the same line is encountered.

3.6 RECOGNITION OF INTERNAL BOUNDARY OF BLANK

A search similar to that of internal feature recognition is performed on the "DASHED" list. However, instead of left and right boundary of the external features, right and left boundaries of the blank are considered.

Once all the features are recognized, the linked lists

are concatenated in such away that two lists; one for the finished part and the other for the blank are obtained. These two lists represent the profiles which when rotated about the axis of symmetry will generate finished part and blank respectively. (see Fig 3.3).

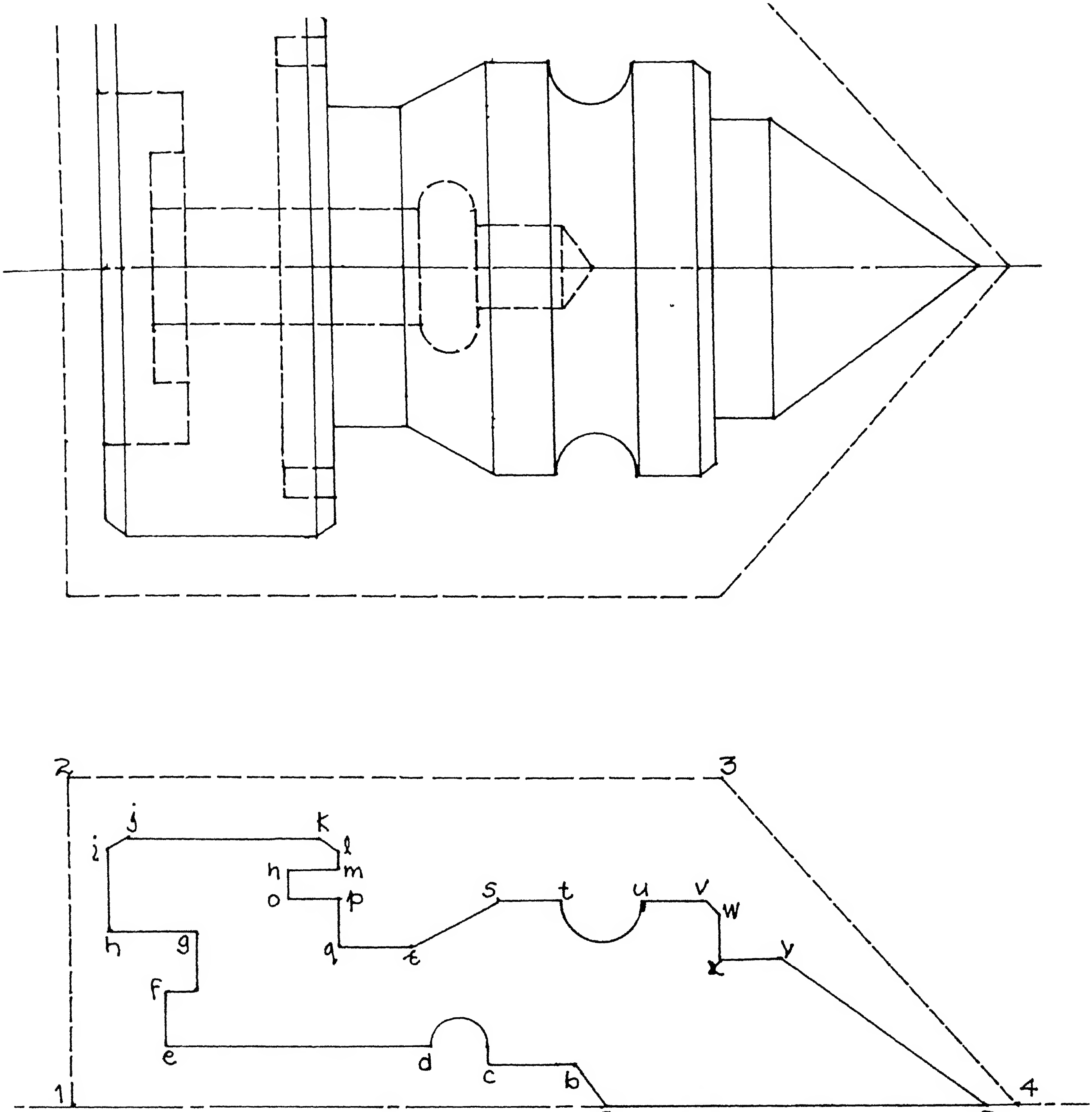
3.7 OUTPUT FORMATS

It is possible to present the output of the feature extraction procedure in two different ways. The two formats are briefly described below.

3.7.1 CIMS/DEC FORMAT

First, from the linked list for profiles, it is possible to generate an output in Kakino's CIMS/DEC format. As mentioned earlier this format can be further used as data for many manufacturing functions. In the present work, the output is interfaced with another software for generating a process plan. The software developed by Shankar Narayana [13], was suitably modified for interfacing purposes.

CIMS/DEC presentation stores both geometric and technological data about the profile element. A geometric data of an element is a locus for profile while technological information includes tolerances, surface roughness, the type of surface generated by sweep of the profile etc.. The object generated by sweep of the profile element is called constituting shape element.



Blank Profile : 1-2-3-4
Finished Part profile : a-b-c-d .....x-y-z

Rotation of the blank profile and part profile about XX axis will generate blank and finished part respecively.

Fig 3.3 FINISHED PART AND BLANK PROFILES

The present work extracts geometric data and technological information like constituting shape element etc.. However, it fails to extract technological data related to tolerances and surface finish and work material.

In addition to the shape elements discussed, there are some subsidiary shape elements comprising the technological shape elements like screw, knurled surfaces and connecting shape elements like chamfer etc. The subsidiary shape elements are ignored as they do not fall under category of axi-symmetric parts.

All the information about the profile elements is stored in a data structure comprising of the following fields.

1. Element number.
2. Shape symbol (Table 1 shows shape symbols).
3. Dimension in X-direction.
4. Dimension in Z-direction (Y- direction in previous discussion).
5. Technological information (surface finish, default value: 50 microns).

All the profile elements are traversed in clockwise direction after starting from any point on profile.

Table 1 Shape elements in rotational parts description

Shape Elements		Types of Elements	Shape Symbols
Constituting Shape Elements		Plane Surface	P
		Cylindrical Surface	C
		Conical Surface	T
		Doughnuts-like Surface	D
		Sculptured Surface	S
Subsidiary Shape Elements	Technological Shape Elements	Screwed Surface	Sc
		Knurled Surface	Kn
		Geared Surface	Ge
		Splined Surface	Sp
		Sprocket Surface	Sr
	Connecting Shape Elements	Chamfered Surface	c
		Round Surface	r
		Hollowed Surface	h
	Specific Shape Elements	Hole with Different Coordinates	Ho
		Groove with Different Coordinates	Gr
		Plane with Different Coordinates	Pl

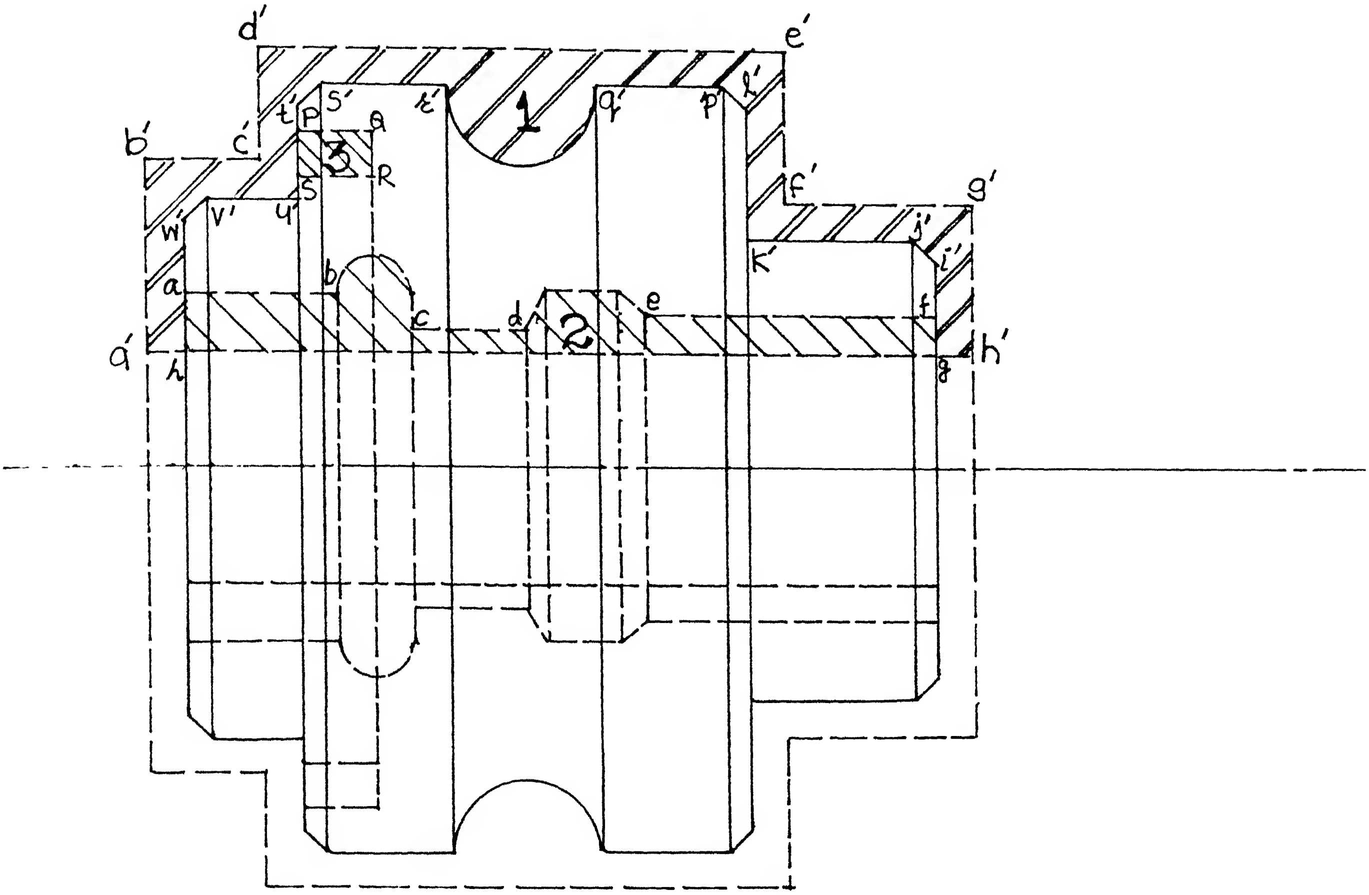
3.7.2 THE PROFILE SEGMENT DESCRIPTION FORMAT

It is clear from the foregoing discussion that CIMS/DEC format does not consider blank profile. However, in practice, it is necessary to consider the blank configuration in the feature extraction process since the blank may be of intricate shape as in the case of forgings/casting.

In the profile segment description format, the contour which forms a feature is presented. Fig 3.4 shows various contours corresponding to different features. The areas enclosed by the contours can be decomposed into smaller quadrilateral, triangles and chords of an arc. The decomposed areas can further be analyzed to give features. As the auxiliary features are already separated in the profile segment format, the complexity of differentiating depressions on lateral faces from the external features is avoided automatically. This makes feature extraction a bit simpler.

In the present work, the decomposition aspect has not been fully implemented. Partial implementation has been along the following lines :

Certain conditions need to be conceived to facilitate the decomposition of the feature. A few of the conditions are outlined here.



1 : External Feature formed by profile :
a'-b'-....h'-g-i'-...w'-h-a'

2 : Internal Feature formed by profile :
a-b-c-..f-g-h-a

3 : Auxiliary Feature formed by profile :
P-Q-R-S-P

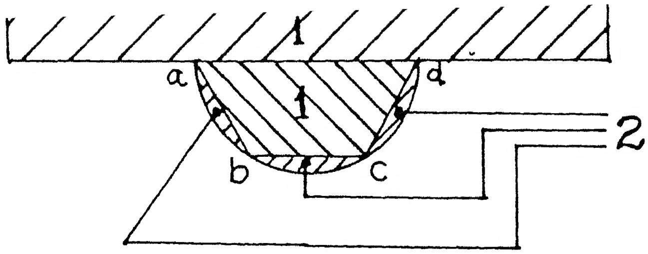
Fig 3.4 AREAS PRESENTED IN THE PROFILE DESCRIPTION FORMAT

1. If the left or right boundary of an external feature list is a vertical line, then triangle/quadrilateral which has got the left or right boundary as one of its sides, forms a facing feature.

2. In case of an arc segment which indicates a projection, the arc can be enclosed by a trapezoid. The area enclosed between such a trapezoid and the arc indicates the presence of a special feature which can be removed using either a form tool or contour turning operation. Similarly, if the arc indicates a groove/depression, a trapezoid which is circumscribed by this arc can be drawn. The selected trapezoid should be such that maximum possible area from the chord is removed (see Fig 3.5 for illustration.)

3 . The linked list for the external features can be used for determining the chucking side. By traversing the list, one can determine the profile trend like increase in diameter of an object when one moves from the left boundary to the right boundary. Reverse procedure can be adopted to establish the decreasing profile trend. Using the profile trend information, chucking side can be determined.

Other conditions on similar lines can be developed to facilitate the decomposition and extraction of manufacturing information.

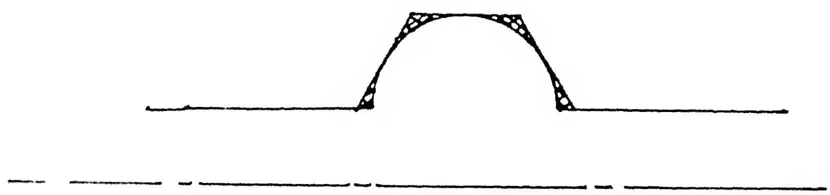


Arc a-b-c-d forms a curved groove.

Trapezoid ABCD is circumscribed by the arc.

Area 2 is a special feature.

Fig 3.5 (a) DECOMPOSITION OF CURVED FEATURES (DEPRESSION)



Shaded area is a special feature.

Fig 3.5 (b) DECOMPOSITION OF CURVED FEATURES (PROJECTION)

3.8 INTERFACING WITH AN EXISTING CAPP SOFTWARE

The output in CIMS/DEC format becomes the input to the CAPP software developed by Narayana [13]. The CAPP software used here is interactive and user is required to key in data in the interactive mode. As this software runs in the DOS environment, interfacing without human intervention of present work with this software is very difficult. Therefore, integration of the two softwares was achieved through user interaction. However, this problem can be circumvented by writing both the softwares (feature extraction as well as CAPP) suitable for the same environment.

Following are some of the limitation of the CAPP software developed by Narayana [13].

1. The process plan generated by the software is based on the data-base provided by the software. As such the software does not provide any append or edit facility for enriching the data-base.

2. The CAPP software does not process through holes and curved surfaces. However, internal features on both the sides can be planned for processing. Moreover, it considers only solid cylindrical blanks, eventhough, in practice, forgings and castings of intricate shapes are used in order to save machining time and material cost. Therefore, it would have been better if the blank configuration was considered in process planning.

3. The CAPP module, which is at the downstream side of the present work, does not consider curved surfaces. For such a part, if CIMS/DEC output is desired; the feature extraction software flashes an error message on the occurrence of the curved surface. However, the profile segment description of the same part can be obtained.

CHAPTER IV

RESULTS AND TEST RUNS

The primary objective of the present work has been to develop an interface between CAD and CAM systems. In the proposed system, the drawing output of CAD system is read and manufacturing information is presented in two different formats. One of them is the CIMS/DEC format.

Figure 4.1 displays the system's output for an illustrative part. The top-left corner of the figure shows the input drawing while the top-right displays the profile which when rotated about the axis of symmetry generates the required object. The bottom-left window shows the user's interaction with the system while the bottom-right window shows the output for the given object in the CIMS/DEC format.

Figures 4.2 and 4.3 show the output windows if the desired output is in the profile segment description format. In this format, geometric/topological information of each element of the profile is presented. Such information about each profile, alongwith the information about the axis of symmetry can be further used to extract technological information about the profile. Figure 4.4 shows input drawing and the extracted profile for two illustrative drawings. As pointed out in section 3.8, the decomposition procedure has been implemented in a limited fashion. Therefore,the results on this aspect have not been presented.

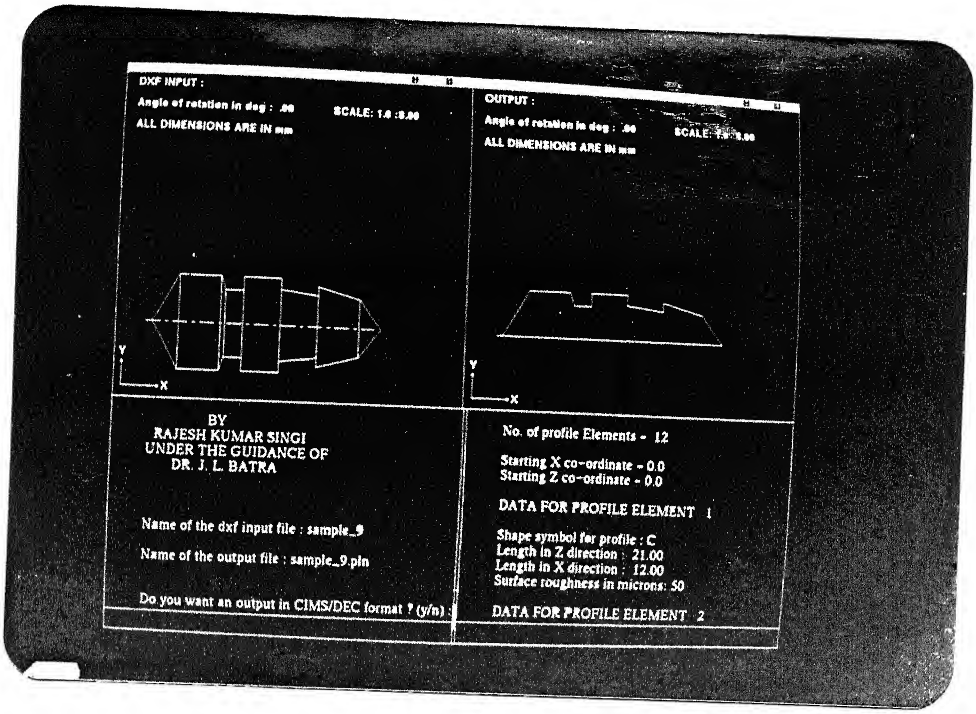


Fig 4.1 OUTPUT WINDOWS OF THE SOFTWARE (CIMS/DEC FORMAT)

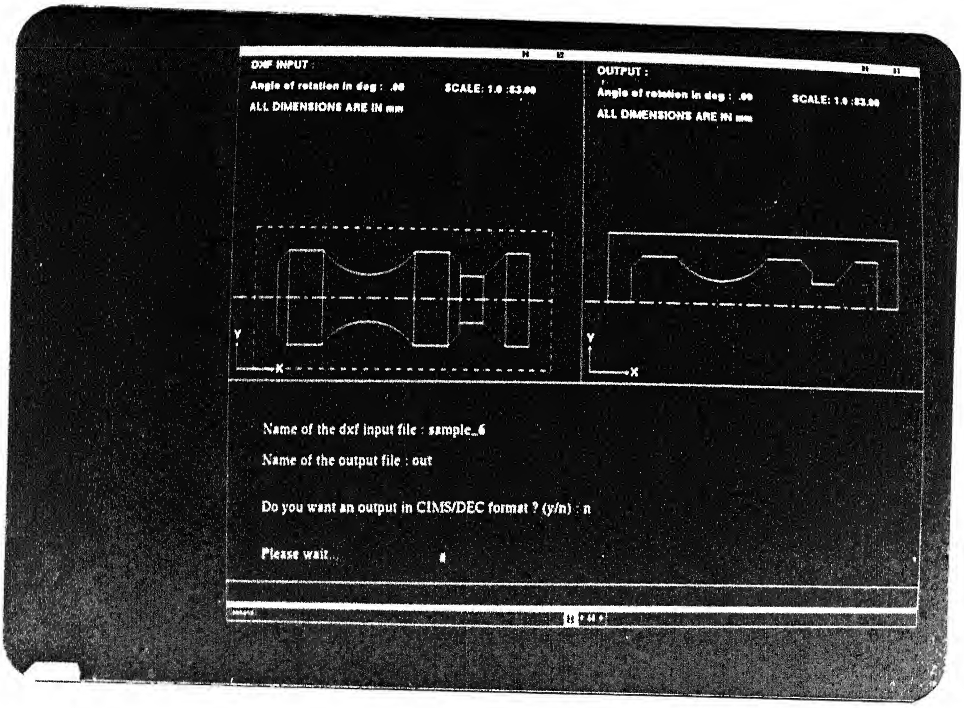


Fig 4.2 OUTPUT WINDOWS FOR PROFILE DESCRIPTION FORMAT

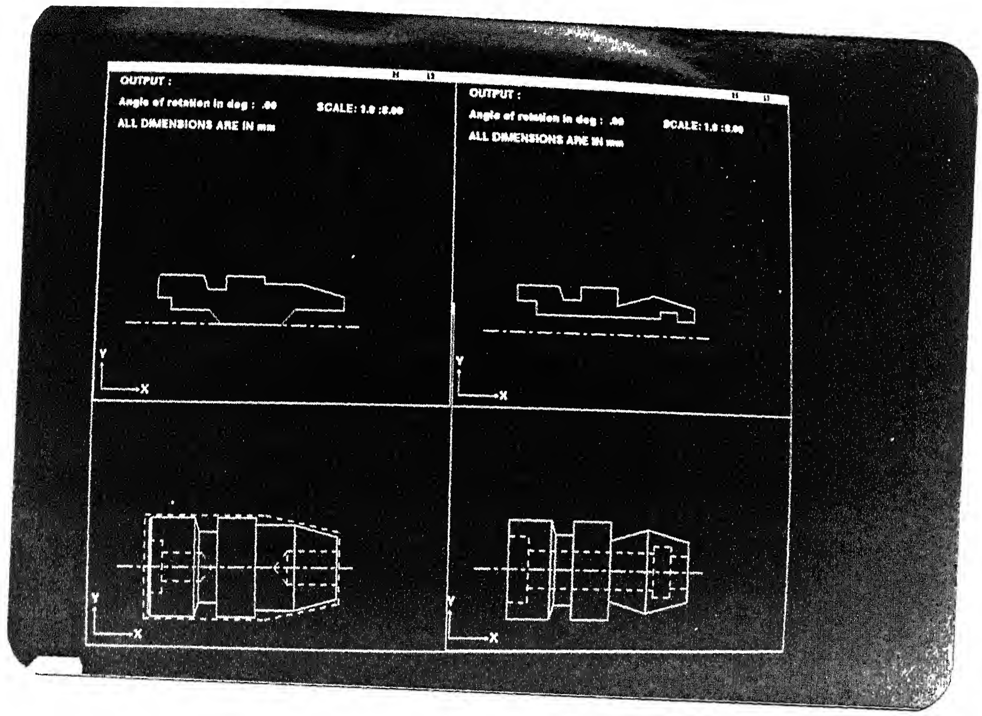


Fig 4.3 OUTPUT FOR DRAWING WITHOUT BLANK CONFIGURATION

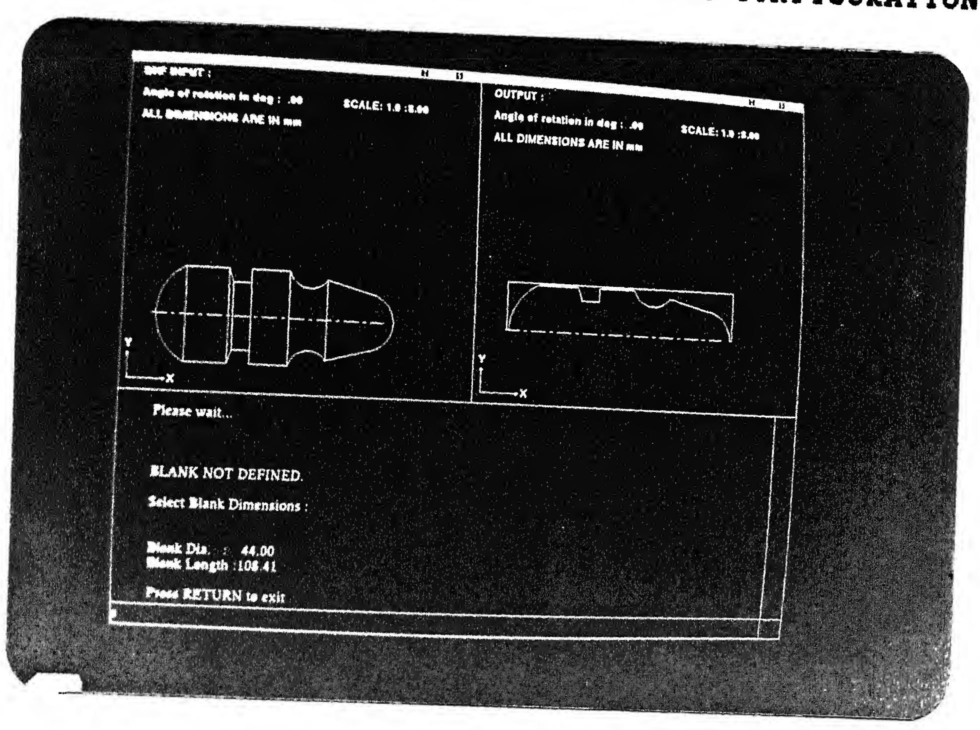


Fig 4.4 OUTPUT FOR TWO ILLUSTRATIONS

The example discussed in Narayan's M.Tech thesis is used to demonstrate the integration aspect of the proposed software with a CAPP software for testing purpose. Figure 4.5 shows the drawing of the example. The DXF file for the drawing is created by following the procedure described in the user's manual (given as Appendix-I).

The DXF output, thus generated becomes the input to the feature extraction software. The CIMS/DEC format output as generated by the proposed software is displayed in fig 4.6.

This output is interfaced the CAPP software. The generated process plan is shown in fig 4.7.

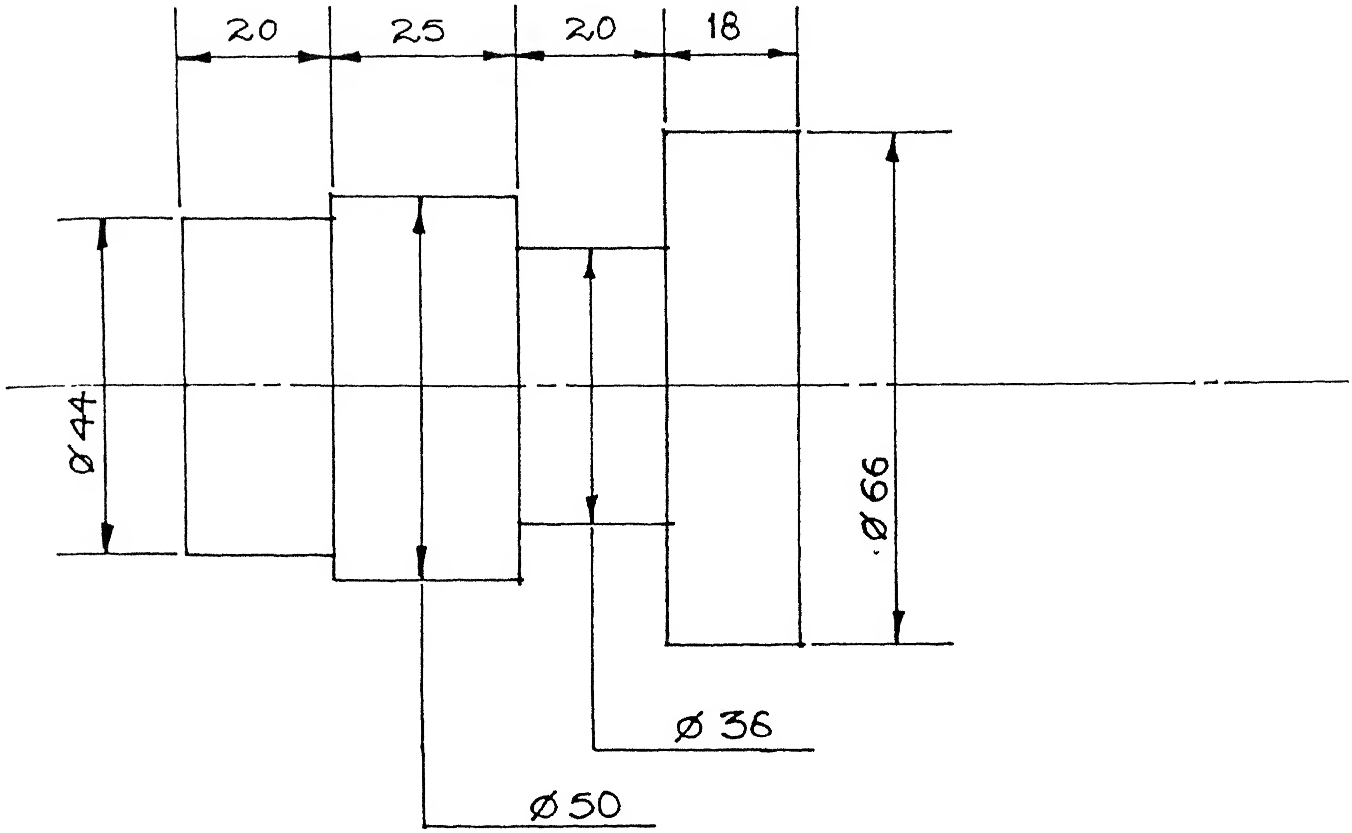


Fig 4.5 DRAWING FOR EXAMPLE 1

*** OUTPUT FOR INTERFACING ***

All dimensions are in mm.
Surace roughness values mentioned here are default one and are in microns. User is required to enter desired value while feeding data to next module.

**** DATA FOR INTERFACING ***

No. of profile Elements = 10

Starting X co-ordinate = 0.0
Starting Z co-ordinate = 0.0

DATA FOR PROFILE ELEMENT 1

Shape symbol for profile : P
Length in Z direction : 22.00
Length in X direction : 0.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 2

Shape symbol for profile : C
Length in Z direction : 0.00
Length in X direction : 20.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 3

Shape symbol for profile : P
Length in Z direction : 3.00
Length in X direction : 0.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 4

Shape symbol for profile : C
Length in Z direction : 0.00
Length in X direction : 25.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 5

Shape symbol for profile : P
Length in Z direction : -7.00
Length in X direction : 0.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 6

Shape symbol for profile : C
Length in Z direction : 0.00
Length in X direction : 20.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 7

Shape symbol for profile : P
Length in Z direction : 15.00
Length in X direction : 0.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 8

Shape symbol for profile : C
Length in Z direction : 0.00
Length in X direction : 18.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 9

Shape symbol for profile : P
Length in Z direction : -33.00
Length in X direction : 0.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 10

Shape symbol for profile : A
Length in Z direction : 0.00
Length in X direction : -83.00

Blank Length : 105.00
Blank Dia. : 78.00

PROCESS PLAN

Example_1

WORK MATERIAL :MEDIUM STEEL

Blank Length (mm.) .105.00
Blank Diameter (mm.) :78 00

Opn. No.	Ele.No.	Operation	M/C Tool	Scrap (mm.)	No of Passes	RPM	Velocity (m/min)	Tool Matl.	feed (mm/rev.)	M/C time (sec.)	C.Fluid
1	9	Face Turning	UTM	2 00	1	742	153.81	CERAMICS	0.80	3 3	DRY/EP-EM/EP-CH
2	8	Turning	UTM	6.00	3	742	153.81	CERAMICS	0.80	25.2	DRY/EP-EM/EP-CH
3	4	Turning	UTM	14.00	6	979	153.81	CERAMICS	0.80	29.9	DRY/EP-EM/EP-CH
4	2	Turning	UTM	17.00	7	1113	153.81	CERAMICS	0.80	18.9	DRY/EP-EM/EP-CH
5	6	Turning	UTM	21.00	9	1360	153 81	CERAMICS	0.80	9.9	DRY/EP-EM/EP-CH
6	1	Face Turning	UTM	21.50	9	1113	153.81	CERAMICS	0.80	13.3	DRY/EP-EM/EP-CH

Cutting Fluids .

CL .Chlorinated paraffin
EP ·Extra pressure oil(S,Cl,P)
FO :Fatty oils(synthetic palm oil);
CH :Water based chemical solutions

EM ·Emulsion
FA :Fatty acids & alcohols
MO .Mineral oil
KO ·Kerosine

Machine tools ·

UTM :Universal Turning Machine
HMC :Horizontal Machining Centre
VMC :Vertical Machining Centre

Fig 4.7 PROCESS PLAN GENERATED BY CAPP SOFTWARE FOR EXAMPLE 1

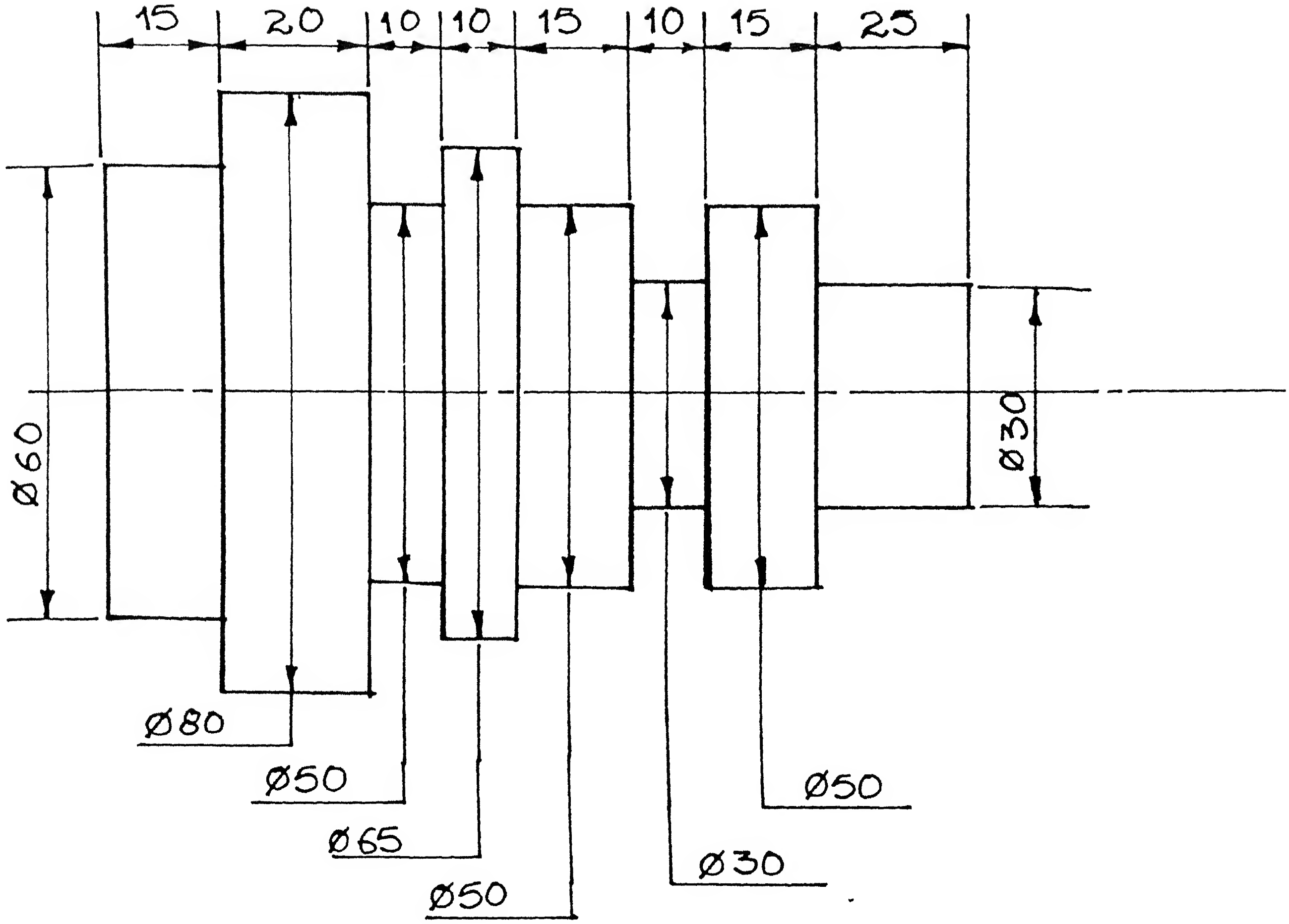


Fig 4.8 DRAWING FOR EXAMPLE 2

**** DATA FOR INTERFACING ***

All dimensions are in mm.
Surface roughness values mentioned here are defau one and are in microns. User is required to ent desired value while feeding data to next module.

**** DATA FOR INTERFACING ***

No. of profile Elements = 18

Starting X co-ordinate = 0.0
Starting Z co-ordinate = 0.0

DATA FOR PROFILE ELEMENT 1

Shape symbol for profile : P
Length in Z direction : 30.00
Length in X direction : 0.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 2

Shape symbol for profile : C
Length in Z direction : 0.00
Length in X direction : 15.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 3

Shape symbol for profile : P
Length in Z direction : 10.00
Length in X direction : 0.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 4

Shape symbol for profile : C
Length in Z direction : 0.00
Length in X direction : 20.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 5

Shape symbol for profile : P
Length in Z direction : -15.00
Length in X direction : 0.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 6

Shape symbol for profile : C
Length in Z direction : 0.00
Length in X direction : 10.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 7

Shape symbol for profile : P
Length in Z direction : 8.00
Length in X direction : 0.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 8

Shape symbol for profile : C
Length in Z direction : 0.00
Length in X direction : 10.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 9

Shape symbol for profile : P
Length in Z direction : -8.00
Length in X direction : 0.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 10

Shape symbol for profile : C
Length in Z direction : 0.00
Length in X direction : 15.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 11

Shape symbol for profile : P
Length in Z direction : -10.00
Length in X direction : 0.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 12

Shape symbol for profile : C
Length in Z direction : 0.00
Length in X direction : 10.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 13

Shape symbol for profile : P
Length in Z direction : 10.00
Length in X direction : 0.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 14

Shape symbol for profile : C
Length in Z direction : 0.00
Length in X direction : 15.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 15

Shape symbol for profile : P
Length in Z direction : -10.00
Length in X direction : 0.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 16

Shape symbol for profile : C
Length in Z direction : 0.00
Length in X direction : 25.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 17

Shape symbol for profile : P
Length in Z direction : -15.00
Length in X direction : 0.00
Surface roughness in microns: 50

DATA FOR PROFILE ELEMENT 18

Shape symbol for profile : A
Length in Z direction : 0.00
Length in X direction : -120.00

Blank Length : 142.00
Blank Dia. : 92.00

PROCESS PLAN

sample_2

WORK MATERIAL : BRONZE
Blank Length (mm.) :142.00
Blank Diameter (mm.) :92.00

Opn No.	Ele.No.	Operation	M/C Tool	Scrap (mm.)	No. of Passes	RPM	Velocity (m/min)	Tool Matl.	feed (mm/rev.)	M/C time (sec.)	C.Fluid
1	17	Face Turning	UTM	2.00	1	1668	157.19	CERAMICS	0.80	0.7	MO-EM/FO-MO/CH
2	4	Turning	UTM	6.00	3	625	157.19	CERAMICS	0.80	43.2	MO-EM/FO-MO/CH
3	8	Turning	UTM	13.00	6	758	157.19	CERAMICS	0.80	59.4	MO-EM/FO-MO/CH
4	2	Turning	UTM	16.00	7	834	157.19	CERAMICS	0.80	56.7	MO-EM/FO-MO/CH
5	14	Turning	UTM	21.00	9	1001	157.19	CERAMICS	0.80	50.6	MO-EM/FO-MO/CH
6	10	Turning	UTM	21.00	9	1001	157.19	CERAMICS	0.80	50.6	MO-EM/FO-MO/CH
7	6	Turning	UTM	21.00	9	1001	157.19	CERAMICS	0.80	50.6	MO-EM/FO-MO/CH
8	16	Turning	UTM	31.00	13	1668	157.19	CERAMICS	0.80	20.5	MO-EM/FO-MO/CH
9	12	Turning	UTM	31.00	13	1668	157.19	CERAMICS	0.80	20.5	MO-EM/FO-MO/CH
10	1	Face Turning	UTM	21.50	9	834	157.19	CERAMICS	0.80	24.3	MO-EM/FO-MO/CH

Cutting Fluids :

CL :Chlorinated paraffin	EM :Emulsion
EP :Extra pressure oil(S,Cl,P)	FA :Fatty acids & alcohols
FO :Fatty oils(synthetic palm oil);	MO :Mineral oil
CH :Water based chemical solutions	KO :Kerosine

Machine tools :
UTM .Universal Turning Machine

CHAPTER V

CONCLUSIONS AND SUGGESTIONS

5.1 CONCLUSIONS

In most of the industries around the world, computers are being used for design and manufacturing activities separately. However, for the unmanned manufacturing factory of the future, it is necessary to develop a control software for smooth interfacing of the CAD and CAM systems. The present work is an attempt on the development of such an interface software. The software is developed for UNIX environment in C programming language.

In the present work, the drawing information of an axi-symmetric part is read and used to generate manufacturing information. The DXF file of the drawing drawn in the drafting software viz.,. AutoCAD, is the input to the present work. The DXF file is decoded and the drawing errors, overwritten lines and arcs are removed. The set of lines and arcs thus obtained are stored in a linked list.

The linked lists are used for various search operations. The set of lines and arcs are formed out of the lines and arcs present in the linked list. Such sets are called profiles. Rule based approach is used for the extraction of the profile features. The various profiles thus generated are classified as internal, external and auxiliary. The profiles when concatenated in a proper manner generate a single profile which when rotated about an axis of symmetry generates the finished

object. Similar procedure is adopted for the blank configuration. The area enclosed between two profiles is decomposed for the extraction of the features.

The output of the feature extraction module becomes available in two different formats; viz., CIMS/DEC format and the profile segment description. The output in the CIMS/DEC format has been interfaced with an existing CAPP software. The results obtained by the proposed software and its interfacing with the CAPP software for two test problems have been discussed.

The output in the profile description format can be used for extracting manufacturing information. Though this particular aspect of the problem has not been fully explored in the present work, yet the direction to be taken to accomplish this have been outlined.

5.2 SUGGESTIONS

In the present work, we have demonstrated a rule-based approach for the extraction of the features. The proposed approach has certain limitations. It is limited only to axi-symmetric objects. Therefore , there is a need to extend the present work to encompass other shapes. however ,it may be noted, that the complexity of the problem substantially increases as scope is widened. The use of the technique do provide opportunities for the development of generalized software for for feature extraction. Further, solid modeler's internal representation scheme may prove to be superior for the

representation of prismatic components which can not be generated by sweep of one type alone.

The present software fails to recognize threaded and knurled parts. Further extensions are required for extraction of these features.

The decomposition procedure for the area enclosed between blank and the finished parts has been implemented only in a limited fashion. Suitable conditions need to be developed for considering all types of areas and configurations.

The feature extraction software developed in this work is for the UNIX environment,while CAPP software with which it has been integrated was developed for the DOS environment. This has resulted in certain interfacing problem viz., user's interaction to provide some of the inputs for the CAPP software. It would be desirable to have proven software for the UNIX environment so that integration without human interfacing becomes possible.

APPENDIX I

USERS MANUAL

The purpose of this manual is to describe the software developed as a part of the present work and to guide the user in effectively using it. This is primarily intended as a reference manual and expects some knowledge of drafting software AUTOCAD and UNIX operating system.

The present software deals with drawings drawn in AUTOCAD by observing the constraints mentioned in the chapter 2 strictly. It produces output in two formats. One is in CIMS/DEC format which is meant for interfacing purpose. Other format is a list of profile elements forming a particular feature. The work is implemented in "C" programming language and runs on APOLLO work-stations in UNIX operating system.

Following are the source files of the program:

1. feature_out.c : It is a main program i.e. outermost shell program. In the program various routines are called from various libraries.

2. dxfread.c : This file contains all the functions required for reading of DXF file, storing drawing information, and correcting drawing.

3.dxfread_c.h : This is a header file for dxfread.c which contains function declaration for all the functions defined in the dxfread.c.

4.feature.c :This is a file which contains all function definitions of the functions required for feature extraction from data stored in the list. It also contains functions for output format.

5.feature_c.h :This is a header file for feature.c file.

6.graphics.c :This file contains functions required for displaying input drawing and output profiles.It is required for graphic display of the results.

7.graphics_c.h :This is a header file for graphics.c file.

8.link_all : This is a make file for compiling and linking a main file and library files.

PROCEDURE FOR EXECUTION

The DXF file for the drawing can be generated by using DXFOUT command of AUTOCAD. The system prompts for precision. The precision should not be greater than 3 digits. This DXF file is required to be transferred to UNIX ^M character from the file. This character is

generated in all ASCII files generated in DOS environment for every carriage return in the file.

The object file feature-out for feature_out.c is executed now.The system then prompts for input and output file name. The user is provided with choice of output format which will be written in the output file at the end of the execution of the program. Various error messages appearing during execution are discussed in the chapter 4. User is suggested to refer it.

REFERENCES

1. Mikell P. Groover and Emory W. Zimmer,Jr., "CAD/CAM : Computer Aided Design and Manufacturing", Prentice Hall Of India(1985);

2. Inyong Ham and Stephen C.Y. Lu, " Computer Aided Process Planning: The Present and The Future", Annals Of CIRP, Vol 37/2/1988 pg 591-601.

3. Chang T. A. and Wysk R. A., " An Introduction to Automated Process Planning System", Prentice Hall International (1985).

4. AUTOCAD Release 10.00: Reference Manual Installation and Performance Guide, Autodesk, Inc.

5. Rong-Kwei Li, "A Part Feature Recognition System for Rotational Patrs", Int J.Prod. Res, 1888, vol 26, No 9, pg 1451-1475.

6. Kakino Y., "A New Method of Part Feature Description For Computer Aided Production Planning", Advances In Computer Aided Manufacture", Edited by D. McPherson, North-Holland Publishing Co, (1977) pg 197-213.

7. Woo T. C., "Computer Aided Recognition of Volumetric Designs", Advances In Computer Aided Manufacture", Edited by D. McPherson, North-Holland Publishing Co, (1977) pg 121-135.

8. Kakazu Y. and Okino N., " Pattern Recognition Approach To GT code Generation On CSG", Proceedings Of 16th CIRP Int. Seminar on Manufacturing Systems, Tokyo(1984) pg 10-18.

9. Requichqa A.A.G. and Vanderbrande J., " Automated Systems For Process Planning and Part Programming", Artificial Intelligence In Industry: AI Implication for CIM, Edited by Kuziac A, IFS Publication(1988), pg 301-326.

10. Devies B. J. , " IKBS Process Planning System For Rotational Parts", Intelligent Manufacturing Systems II, Edited by Milacic V. R., Elsevier Science Publishers(1988), pg 27-38.

11. Van't Erve and Kals H.J.J.,"XPLANE, A Generative Computer Aided Process Planning System For Part Manufacturing", Annals of the CIRP 35/2/1986, pg 325-342.

12. Li J., Han Chingping and Ham I., "CORE -CAPP - A Company Oriented Semi-generative Computer Automated Process Planning Systems", Proceedings Of 19th CIRP Int. Seminar on Manufacturing Systems, Pennsylvania State University.(1987).

13. Shankar Narayana, "Computer Aided Process Planning For Machining of Rotational and Prismatic Parts", M. Tech Thesis, 1989, IIT Kanpur.